RAW MATERIALS

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EXPANSION OF THE GLASS SAND BASE WITH NONCAPITAL-INTENSIVE TECHNOLOGIES

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Even insignificant fluctuations (fractions of a percent) of such components as iron and aluminum oxides in glass melts cause serious changes in the rheological properties of the melt and heat-exchange conditions in the furnace and in the forming units. Noncapital-intensive technologies for concentration of the feedstock that improve the quality of glassware are proposed.

The quality of glass sands evaluated by their brand is a function of the granulometric composition, content of basic substance — silica, and relatively small amounts of iron and aluminum oxides accompanying the silica.

Stability of the iron oxide content in glass significantly affects heat exchange between flame and melt, inside the glass melt in the furnace, and heat transfer in heat treatment of glassware, and also the optical and esthetic properties of glassware.

Colorless glass is semitransparent in the short-wave part of the spectrum [1]. It is relatively transparent up to 2.7 μm, less transparent in the 2.7 – 4.4 μm region, and totally nontransparent above 4.4 μm.

At temperatures under 500°C, most emissions are in the long-wave part of the spectrum and radiant heat exchange plays an insignificant role. At temperatures of 1550 – 1200°C, up to 90% of heat transfer is by the radiant constituent.

With a high iron oxide content in the glass melt, the heat flow from flame to melt in a tank furnace decreases, which leads to fuel losses. When the iron oxide content decreases, the heat flows in the glass melt increase during operation of the furnace, which can entrain crystalline inclusions from the bottom layers of the glass melt in production flow with an increase in the amount of rejects [2].

A 0.1% increase in the aluminum oxide content alters the viscosity of the glass melt equivalent to decreasing its temperature by 4 – 5°C at viscosity of 10^2 P (melting zone) and by 3°C for viscosity of 10^4 P (cooling zone). We know that the Rules of Technical Operation do not permit such fluctuations in the parameters. Compensating for such changes in the conditions by regulating fuel consumption is not effective due to the high inertia of the furnaces. For large-tonnage glass-melting furnaces, the time constant is 150 – 250 h.

In addition to reducing the thermal efficiency of the glass-melting furnace, a high ($FeO + Fe_2O_3$) and Al_2O_3 content and fluctuations in the content negatively affect the forming conditions.

The Maxwell body is the rheological model of glass [3]:

$$\dot{\varepsilon}_{ij} = \frac{\sigma_{ij}}{\nu} - \frac{\sigma_{ij}\, b\tau}{\nu} = \frac{\sigma_{ij}}{\nu}(1 - b\tau);$$

$$\dot{\sigma}_{ij} = -b\sigma_{ij},$$

where σ_{ij} and ε_{ij} are the stress and strain tensors; $b < 1$ is a constant; τ is the stress relaxation time; $\nu = \tau G$ is the kinematic viscosity (G is the shear modulus).

In the glass melting temperature range, $\tau \approx 10^{-3}$. Then Newton's law describing a viscous, incompressible liquid (the glass melt in this case) acts in the molten state (in the glass-melting furnace) at $\tau \approx 10^{-5}$ and $\sigma_{ij} = G\varepsilon_{ij}$.

In the solid state at $\tau \approx 10^5$ and $\sigma_{ij} = \nu\varepsilon_{ij}$ (Hooke's law), glass is a viscoelastic body [4].

In forming bottle glass, the plunger speed can attain 100 m/sec and even higher. In this case, the glass melt undergoes large deformations in a very short time and does not behave as a Newtonian body (viscous incompressible liquid

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with instantaneous stress relaxation) but as a viscoelastic body whose model is described by Hooke's law. Forming stresses cannot relax, and this results in cracks and crazes, especially in the necks of bottles and jars.

When sands from new deposits are used in production, including those previously qualified as construction sands, it is necessary to not only perform a traditional general granulometric analysis and analysis of the chemical and mineral compositions but also to investigate their chemical and mineral compositions by fractions in the stage of studying these sands.

In studying a number of sand deposits, it was found that at an overall high iron and aluminum oxide content, they are concentrated in small (< 0.1 mm) and large (> 0.6 mm) clay fractions. We can cite the data from chemical analysis of sands by fraction in the Central and Northwest regions and in Yakutia as an example (see Table 1). The analyses were performed at the Institute of Glass (Moscow), V. I. Vernardskii Institute of Geochemistry and Analytical Chemistry, Russian Academy of Sciences, at the Analytical Certification Testing Center at the All-Russia Institute of Mineral Raw Materials, and the Institute of Comprehensive Utilization of Mineral Raw Materials and Wastes.

As the data in Table 1 suggest, at a total iron oxide content of approximately 0.3%, more than 60% of these oxides are in the < 0.1 mm fraction, which in turn is up to 2.0 – 4.3% in the granulometric distribution of the sand. This fraction contains up to 2/3 Al_2O_3 of the total amount, 3.0 – 4.0%. In sieving the < 0.1 mm fractions, the sands go from grade T, which has restricted use, or is even in the unsuitable category, to grade S-070-1, which is totally suitable for production of brown and green bottles. The difficulties in separation of aluminum and iron oxides are due to the fact that the < 0.1 mm fraction contains an important amount of clay constituents and it cannot be passed through a sieve. Even if this fraction were more noble in composition, process regulations recommend that it be removed.

In the given case, a simple, noncapital-intensive procedure for removing this fraction in the gas-air stream was developed for the concrete enterprise. Up to 7 tons of < 0.1 mm fraction per work shift is extracted from the sand. This sand is then used in construction and in production of building materials.

At a total iron oxide content in the sand of 0.3 – 0.4%, a significant part is contained in the form of weakly magnetic minerals (limonite, pyrite, etc.), almost uniformly scattered over all fractions. In this case, the sand was enriched with special magnetic separators with a powerful magnetic field (strength) of up to 16,000 Oe. This procedure is also noncapital-intensive with implementation at the enterprise.

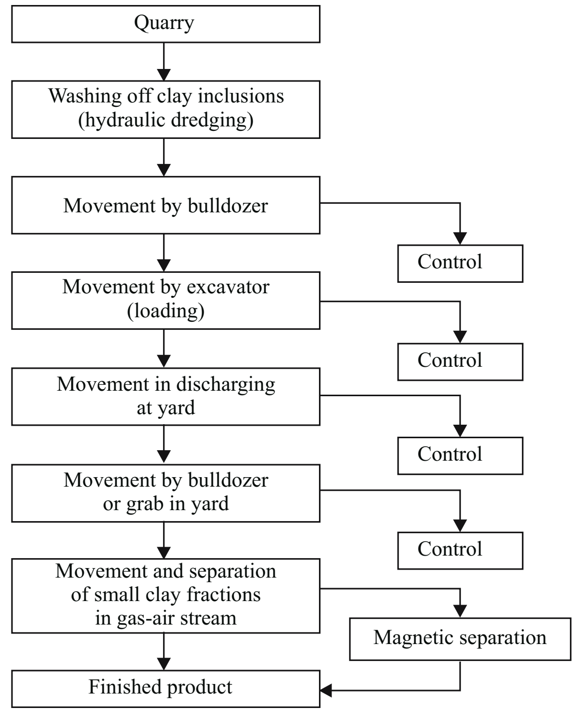

Fig. 1. Diagram of averaging and separation of sand.

We should pause on methods of "gross" averaging and separation of raw materials. They include washing out clay inclusions in extracting the sand with a hydraulic dredger, averaging the washed sands with an excavator, bulldozer, or grab directly at the quarry or factory yard. The advantage of using several feed hoppers or a hopper with several loading or discharging holes should especially be noted [5].

The theoretical calculation showed [6] that in two-hand discharging, the dispersion of the chemical composition of the mixture decreases by almost two times.

Averaging with the universal scheme for separation and averaging of sand does not imply comprehensive concentration of the material, but it allows industrial use of sands which were previously considered unsuitable for glass melt-

TABLE 1

Sand deposit	Fraction		Distribution of Fe_2O_3	
	class, mm	yield, %	mass fraction, %	extraction, %
Gidrouzel Quarry (Central region)	> 0.6	8.2	0.399	16.2
	< 0.6 – > 0.1	88.5	0.115	50.8
	< 0.1	3.3	2.000	33.0
Voibokal'skoe deposit (Northwest region)	> 0.6	1.8	0.512	18.3
	< 0.6 – > 0.1	89.3	0.963	43.8
	< 0.1	8.9	2.720	37.9
Nebolochinskoe deposit, "Western" section (Northwest region)	> 0.6	3.7	0.370	17.7
	< 0.6 – > 0.1	91.3	0.086	41.1
	< 0.1	5.0	3.110	41.2
Tarko-Salinskoe deposit (Yakutia)	> 0.6	9.2	0.327	19.1
	< 0.6 – > 0.1	88.3	0.241	43.3
	< 0.1	2.5	4.320	37.6

ing without important capital outlays. Such sands can be used in production of colored and off-white glass containers, glass insulators, colored glassware, glass fibers, foam glass, and some medical glasses. The refined separation and averaging scheme should be based on a preliminary study of the chemical, granulometric, and mineral compositions of the sand.

The proposed scheme allows using "poor" local sands. In addition, since the material is more homogeneous, conditions are created for accelerating silicate- and glass-formation and obtaining a more homogeneous and higher quality glass melt, as well as for reducing rejects in the forming stage. The proposed scheme is actually zero-waste and the sieved fractions are totally utilized for construction purposes, water filters, etc.

After processing sands from Gidrouzel quarry with the examined scheme, Orekhovo-Zuevsk Glass Company is manufacturing high-quality bottles for such well-known firms as Efes and Baltika. Kirishsk Glass Works is similarly manufacturing high-quality articles.

Even insignificant fluctuations (tenths of a percent) of such components as iron and aluminum oxides in a glass melt can cause serious changes in the rheological properties of the melt and the heat-exchange conditions in the furnace and forming units.

At high mechanical charging speeds, the glass melt does not behave like a Newtonian fluid but like an elastic Maxwell body. Many defects in glassware are due to these phenomena.

Noncapital-intensive technologies for enrichment of raw materials that improve the quality of glassware are proposed.

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